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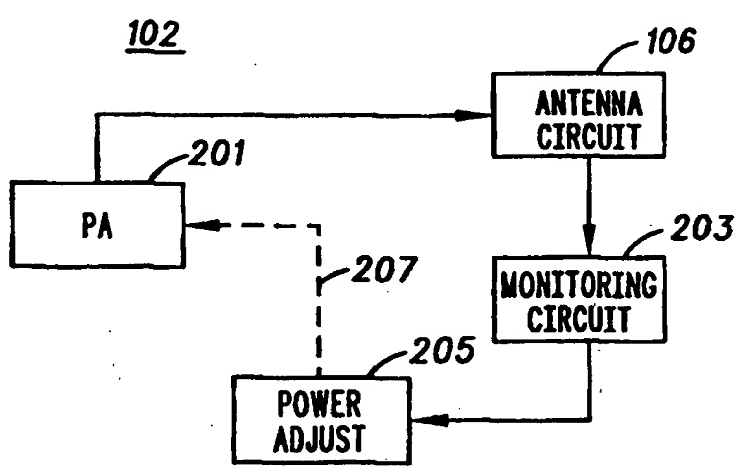
(54) Title: DATA COMMUNICATIONS TERMINAL AND METHOD OF ADJUSTING A POWER SIGNAL GENERATED THEREFROM

(57) Abstract

A data communications terminal (102) includes an antenna circuit (106) for delivering a power signal to a portable data device. The terminal further encompasses a method for automatically adjusting the power seen by the portable data device without any communications feedback from the portable data device by monitoring an impedance characteristic for the antenna circuit. When a change in the monitored impedance characteristics is detected, the data communications terminal adjusts a power level for the power signal delivered to the portable data device.



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DATA COMMUNICATIONS TERMINAL AND METHOD OF ADJUSTING A POWER SIGNAL GENERATED THEREFROM

Field of the Invention

The invention relates generally to a data communication system and in particular to a data communication terminal and method for automatically adjusting a power level in response to a detected change in the data communications terminal.

Background of the Invention

Data communication systems are well known and include a terminal device that communicates with a portable data device in either a contacted or contactless mode. Delivering power from the terminal device to the portable data device in a contacted arrangement is rather easily controlled through the electrical connections of the contact points. In a contactless environment, power delivery and regulation can be a more complex problem. In particular, it is imperative that the portable data device receives enough energy to maintain a suitable power level for the card circuitry, but not too much power so that the device circuitry begins to overheat.

To help explain the dynamics of a card receiving too much power, FIG. 1-1 shows a data communication system 100 that includes a terminal device 102 in relation to a portable data device 104. As shown, the transmitting element 106 of the terminal device 102 is separated from the receiving element 108 of portable data device 104 by a distance, D. It is well understood that the amount of energy seen by the portable data

device 104 is directly related to the distance, D, between the card and the reader. That is, as the card comes closer to the reader, the card must adapt to the increased energy by somehow regulating the power to maintain a constant level.

FIG. 1-2 shows a graphical depiction of the relationship between the distance, D, and the card power, P_C. The power curve 110 shows an exponentially decreasing relationship between the card power and the distance between the card and the reader. To maintain proper operating conditions, there is a minimum distance 112 that the card can be separated from the reader. At this distance, the card sees the maximum power that can be tolerated by the circuitry on the card. When the card moves closer to the reader, the excess power must be absorbed by any number of known means, such as resistive elements, etc. When the card and reader are separated by a distance shown in region 116, the card must continually absorb the excess power so that the card circuitry is not damaged. Of course, power absorbed in resistive elements generates heat, which can build up and cause deleterious effects on the card substrate (usually some form of plastic). Likewise, as the card moves away from the reader, as depicted in region 118, the power seen by the card decreases to a minimal acceptable level 120 at a maximum allowable distance 122.

While the problem of minimum power levels are being addressed by advanced reception techniques, the problem associated with maximum power levels that result in card over-heating remain persistent in today's smart cards. Prior art techniques that address this problem require that the card remain in communication with the terminal, allowing for a feedback mechanism to request that the terminal deliver less power. The need for communication from the card to the reader becomes a problem when, for one reason or another, the card ceases communicating with the reader. One such scenario is when the card loses synchronization with the

reader, whereby the feedback mechanism is lost. Another scenario is when the card and reader do not communicate in the same format. In either case, the card is unable to convey to the reader the presence of excess power, and overheating results. In fact, a card IC could get so hot that it could distort the plastic and cause thermal damage to semiconductor junctions, thereby rendering the card useless.

Accordingly, there exists a need for a data communication system terminal and method for adjusting a power level for delivery to a portable data device. In particular, a data terminal that could automatically adjust the power level without requiring communications between the card and reader (e.g., a request from the card to adjust the power level) would be an improvement over the prior art.

Brief Description of the Drawings

FIG. 1-1 shows a data communication system, as is known in the art;

FIG. 1-2 shows a power curve that relates detected power levels with distance between the terminal and portable data devices shown in FIG. 1-1;

FIG. 2 shows more detailed diagram of a terminal device, in accordance with the present invention;

FIG. 3 shows a simplified schematic diagram of a power delivery mechanism, in accordance with one embodiment of the present invention;

FIG. 4 shows a simplified schematic diagram showing several impedance detection techniques, in accordance with the present invention;

FIG. 5 shows a simplified schematic diagram depicting a power regulation circuit, in accordance with the invention; and

FIG. 6 shows a data flow diagram depicting operation of a terminal device, in accordance with the present invention.

Detailed Description of a Preferred Embodiment

The present invention encompasses an apparatus and method for use in a data communications terminal that includes an antenna for delivering a power signal to a portable data device. The data communications terminal monitors an impedance characteristic for the antenna, attempting to detect a change in the monitored impedance characteristic thereof. When a change is detected, the data communications terminal automatically adjusts a power level of the power signal delivered to the portable data device. In this manner, the present invention allows for a communication-less means by which the power delivered to the card can be adjusted by the terminal (i.e., without the need for the reader requesting a power adjustment).

FIG. 2 shows a simplified block diagram of a data communications terminal 102, in accordance with the present invention. A power amplifier 201 generates and delivers a power signal to the antenna circuit 106, for transmission to the portable data device. During operation, the antenna circuit 106 delivers impedance characteristic information to a monitoring circuit 203, which can be implemented in a number of different ways, as later described. The monitoring circuit 203 is operably coupled to a power adjustment circuit 205, in accordance with the present invention. Finally, the power adjust circuit 205 generates a control signal 207 that is inputted to the power amplifier 201. According to the present invention, the foregoing simplified elements are used to advantageously provide power adjustment without an attendant need to receive a command from the portable data device. Accordingly, it is not necessary that the card and the reader be in communication for a power adjustment to be made

FIG. 3 shows a balanced transmitter circuit that can be used in the power amplifier 201 shown in FIG. 2. The power amplifiers 201-1 and 201-2 are driven by opposite-polarity input signals 302 and 304, such that the voltage swing across the antenna circuit 106 is double what it would be with only a single-ended, unbalanced drive circuit. In a preferred embodiment, the inductor 306 needs to be resonated, at the power amplifier carrier frequency, using resonating capacitors 308, 310 such that the maximum current is obtained through the antenna for a given drive voltage (i.e., out of the power amplifiers). Maintaining a completely balanced circuit for the antenna has the added benefit of controlling radiated emissions, as fewer spurious radiating modes are excited with an antenna that is balanced with respect to ground.

FIG. 4 shows the antenna circuit 106 shown in FIG. 3, along with a plurality of monitoring circuits, in accordance with the present invention. In particular, between nodes 401 and 402 is shown a first monitoring circuit 403. In one embodiment, the current through the inductor 306 is sampled using a series connected primary coil 405 of a transformer circuit, that is completed with the secondary coil 407. The carrier current flowing through the inductor 306 typically has a large amplitude, on the order of 0.5 amps to greater than 1 amp, in order to generate sufficient magnetic field to power a remotely coupled card. By making the turns ratio of the secondary coil 407 to the primary coil 405 high, the sampled current is stepped down to a value appropriate for a high impedance detector circuit 409. In this embodiment, the high impedance detector circuit 409 produces a control signal 410 that is proportional to the current flowing through the antenna circuit 106. Of course, a large turns-ratio lowers the impedance of the detector that is reflected into the primary circuit between nodes 401 and 402, thereby negligibly affecting the series losses in the antenna circuit 106.

The voltage across the inductor 306 (i.e., between the two nodes 411 and 402) can also be sampled as a means of monitoring the impedance characteristic. In one embodiment, the voltage is measured across the nodes by utilizing the inherent subtraction operation of a simple high-impedance differential amplifier 413 to produce a control signal 414. In practice, the voltage swing between nodes 411 and 402 can be very large for a high current system, on the order of 50 Vpeak, so some resistive divider or other means of reducing the voltage across the differential amplifier input nodes may be required (not shown). The voltage across the antenna can produce an impedance characteristic in and of itself, or when used in conjunction with the antenna series-current sense performed by 403 (or 416, as next described), an actual antenna impedance can be calculated from the sensed antenna voltage and current. It should be noted that the differential voltage measurement between nodes 411 and 402 does not generally provide an accurate measure of the antenna current. This is because the actual impedance seen between nodes 402 and 411 is dependent on the proximity of the card to the reader. However, in spite of it's inherent inaccuracy, this voltage measurement is sufficient to generate a control signal for use in a power control method, in accordance with the invention.

A second embodiment for sampling the series current through the inductor 306 (and third technique for monitoring an impedance characteristic) uses a monitoring circuit 416, in which a known series impedance 417 is placed between nodes 411 and 415. This impedance does not have to be resistive; a reactance or complex impedance is also useful, provided the impedance is known. By measuring the voltage drop across nodes 415- 411 with a high-impedance differential amplifier 419, a control signal 420 is generated that is proportional to the antenna series current.

A preferred embodiment for the power amplifier system is shown in FIG. 5, wherein amplifier 501 may be any high-efficiency, saturated-mode amplifier. In a preferred embodiment, a class D amplifier is used. There are several ways the amplifier's output power level can be controlled, in accordance with the present invention. First, by applying the control signal (CS', CS", etc.) to an amplifier power supply circuit 502, which consists of a DC-DC converter 504 and a supply filter 506, the bias to the power amplifier can be adjusted. Adjusting the bias of a saturated-mode power amplifier as a means of adjusting the output power is well understood by those skilled in the art. Another means of adjusting the power in the fundamental frequency coming out of the amplifier is to alter the drive signal to the amplifier with a modulating circuit 508 that will vary the duty cycle of the input drive waveform using a pulse-width modulator. The maximum carrier level can be achieved for a 50% duty cycle. For a pulse width modulated drive waveform having a duty cycle δ, those skilled in the art can show that the fundamental component of the pulse waveform varies as $\sin(\pi\delta)/\pi$. This function has a maximum for $\delta=0.5$, or 50% duty cycle, and falls off symmetrically whether the duty cycle is increased or decreased.

In one embodiment, the voltage sampled across a series impedance is compared to the power amplifier supply voltage. As the presence of the card de-tunes the resonance, the current through the antenna starts decreasing since the card's additional impedance is coupled into the antenna. As the ratio of the sampled current to the power amplifier supply voltage (which serves as an operating impedance characteristic) starts decreasing, the ratio can be monitored. When the monitored ratio falls below a predetermined threshold or outside of a predetermined range, which indicates the proximity of the card, the supply bias can be reduced by a predetermined amount, in accordance with the invention. As

the card recedes from the reader, the ratio again increases, and the power amplifier supply is returned to its initial level.

In some applications, it is preferred to have the antenna remotely located from the power amplifier 501. In such a case, the power signal is directed to the antenna through a standard transmission line, such as a 50 or other standard impedance coaxial cable. To efficiently deliver power to the antenna, it must be impedance-matched to the cable impedance using a matching network 520. Changes in the antenna impedance may be observed at the power amplifier end of the cable by utilizing the impedance characteristic monitoring circuit 512. This circuit consists of a bi- directional coupler 516 which in general consists of coupled transmission lines but for low frequencies such as used in the preferred embodiment, would consist of lumped inductors and capacitors. Such circuits are well known in the art. By comparing the forward and reverse-propagating waves, the reflection coefficient 518 (denoted by 'Γ') can be calculated, which those skilled in the art recognize as another means of representing impedance at the input to the matching network. Through de-imbedding techniques, the effects of the matching network 520 can be removed to yield the actual antenna impedance, if desired. However, knowing the value of Γ is all that is necessary to observe the change in antenna impedance sufficiently well to engage power control.

For a power amplifier that is intended to drive a 50-ohm cable, another means of controlling the output power (i.e., besides power supply control) is to utilize variable attenuator 514, which is driven by a control signal derived from the reflection coefficient 518. For example, in one embodiment, observing the reflected waveform amplitude, which is indicative of the antenna de-tuning due to the proximity of a card, and comparing it to the incident amplitude, a feedback control signal can be generated to control the attenuator or amplifier power supply. It should be noted that, for 50-ohm systems having the antenna located near the

power amplifier, this measurement can be made without the directional coupler by observing the voltage amplitude at the input to the matching network, since the voltage at this point is the sum of the incident and reflected waves. Comparing this amplitude to the "no-card-present" amplitude, which serves as a reference impedance characteristic, the incident wave amplitude can be reduced to keep the incident-plus-reflected amplitude constant. Of course, this approach reduces the power delivered to the card in close proximity, and increases the incident wave to "no-card-present" levels as the card recedes from the reader.

FIG. 6 shows a flow diagram 600 that depicts operation of a data communications terminal in accordance with the present invention. During operation, the terminal monitors (601) its own impedance characteristic for the antenna circuit, as earlier described. A function of the antenna impedance, $f(Z_A)$, is calculated (603) using one or a combination of two of the techniques earlier described. When the calculated impedance is compared with a reference impedance characteristic, which might be a voltage or digital word that corresponds to a preferred operating condition, and determined (605) to be within range, the impedance characteristic is continually monitored (at step 601). In the event that the calculated impedance characteristic falls outside of a predetermined range, the power signal is adjusted (607) by a predetermined amount by the data communications terminal. In particular, if the power signal is either too low or too high, as determined by a corresponding impedance change in the terminal, the power signal is adjusted accordingly. It is important to note that the terminal is able to make an automatic power adjustment based on monitoring its own characteristics. Thus, a card that has lost communication or cannot initiate communication with the reader stands to benefit equally as one that maintains continuous communication with the reader.

The above features describe a communication-less power control system, where, by means of relatively low-complexity circuits, a reader terminal can gather sufficient information about the proximity of a card to effect a transmit power reduction as a card nears a reader. Likewise, transmit power can be automatically increases as a card separates from a previously reduced-power reader. The advantage of not requiring communications lies in the fact that the card may be unable to communicate with the reader because of a difference in communications format or some other non-communicating mode, such as the card being in the field with another card that is controlling the communications link, or an error in the communications link causing lost synchronization. With more and more financial and other sensitive applications relying on the use of contactless smart cards, the amount of information that can be destroyed by overheating a card is increasing dramatically. Accordingly, a terminal and method for adjusting the power levels transmitted therefrom toward a contactless card provide a significant improvement over the prior art.

What is claimed is:

Claims

1. In a data communications terminal that includes an antenna circuit for delivering a power signal to a portable data device, a method comprising the steps of:

monitoring an impedance characteristic for the antenna circuit to produce a monitored impedance characteristic;

detecting a change in the monitored impedance characteristic; and

adjusting, responsive to the step of detecting, a power level for the power signal.

2. The method of claim 1, wherein the antenna circuit is operably coupled between a first node and a second node, and wherein the step of monitoring comprises the step of measuring a voltage level across the first node and the second node.

3. The method of claim 1, wherein the antenna circuit is operably coupled between a first node and a second node, and wherein the step of monitoring comprises the step of measuring a current level flowing between the first node and the second node.

4. The method of claim 1, wherein the step of monitoring comprises the step of calculating an impedance from the monitored impedance characteristic.

5. The method of claim 1, wherein the data communications terminal further includes a bi-directional coupler operably coupled to the antenna circuit, and wherein the step of monitoring comprises the step of measuring a reflection coefficient from the bi-directional coupler and calculating an impedance from the measured reflection coefficient.

6. A data communications terminal, comprising:

a power amplifier;

an antenna circuit, operably coupled to the power amplifier, disposed between a first node and a second node;

a monitoring circuit operably coupled to at least one of the first and second node; and

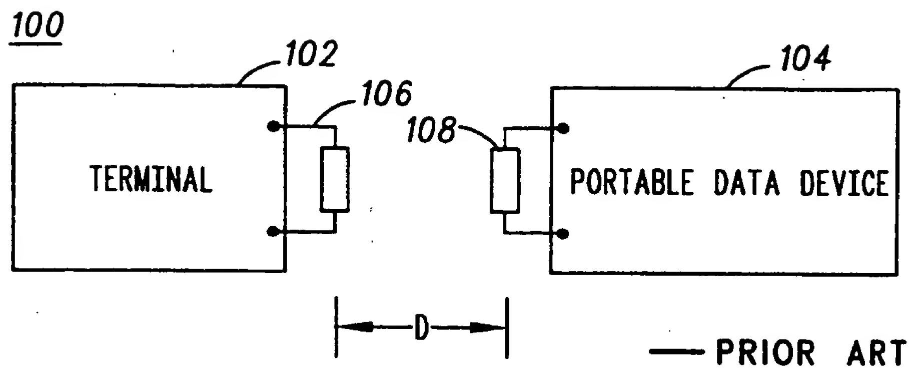
a power adjusting circuit having an input coupled to the monitoring circuit and an output coupled to the power amplifier.

7. The data communications terminal of claim 6, wherein the power amplifier comprises a class D power amplifier.

8. The data communications terminal of claim 6, wherein the antenna circuit comprises two resonating capacitors and a coil disposed therebetween.

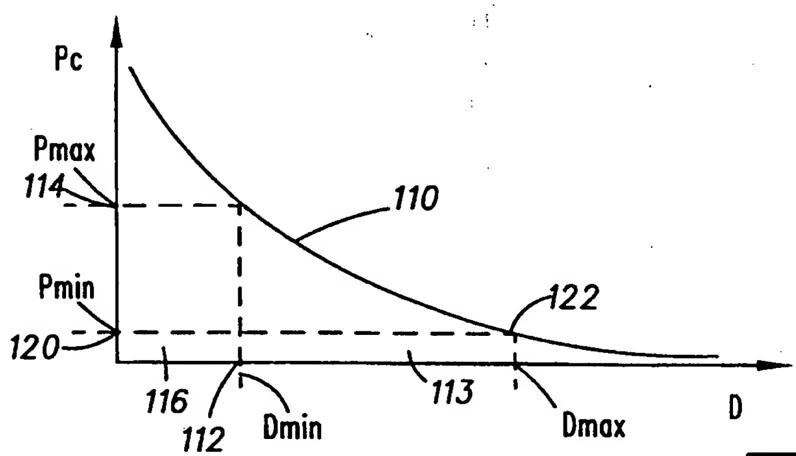
9. The data communications terminal of claim 6, wherein the monitoring circuit comprises a differential amplifier operably coupled to the antenna circuit via the first and second node.

10. The data communications terminal of claim 6, wherein the monitoring circuit comprises transformer means for measuring current through the antenna circuit.



— PRIOR ART —

FIG.1-1



— PRIOR ART —

FIG.1-2

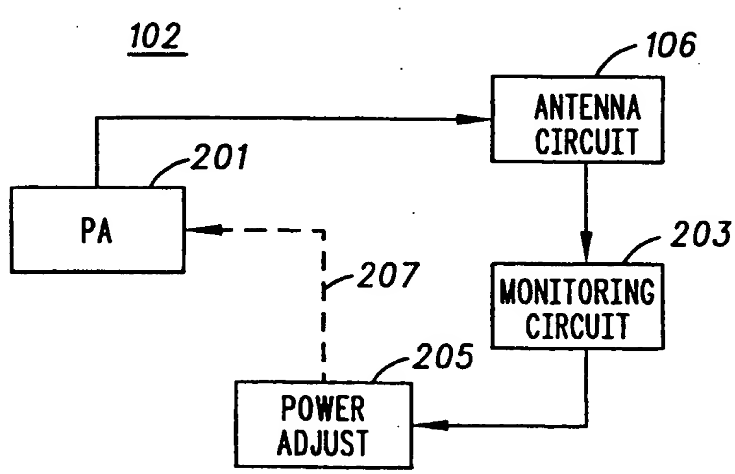


FIG.2

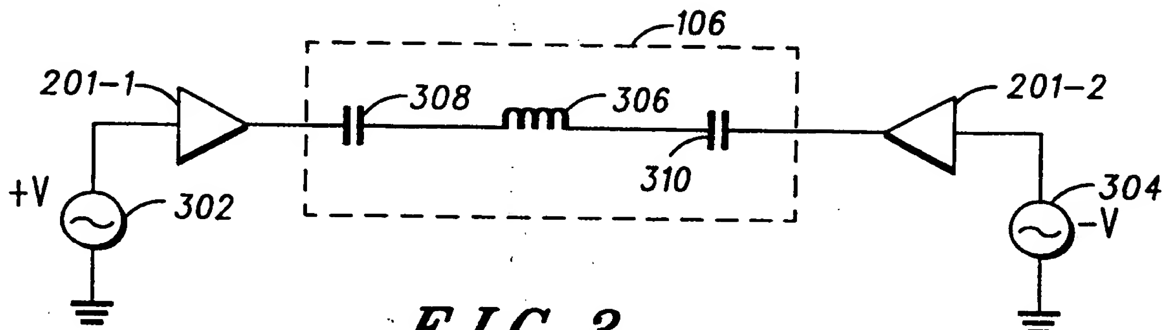

106
201-1
308
306
201-2
310
+V
302
304
-V

FIG.3

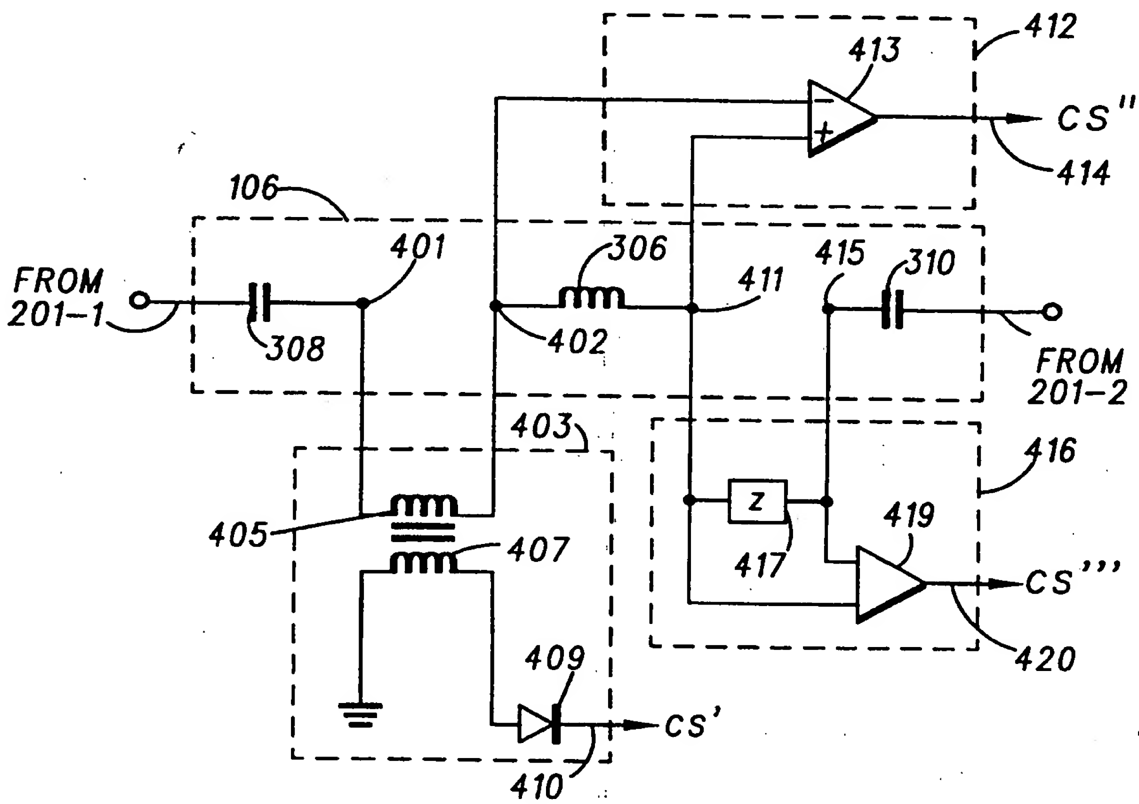

412
413
+
CS''
414
106
401
306
411
415
310
FROM
201-1
308
402
FROM
201-2
403
416
405
Z
419
407
417
CS'''
420
409
CS'
410

FIG.4

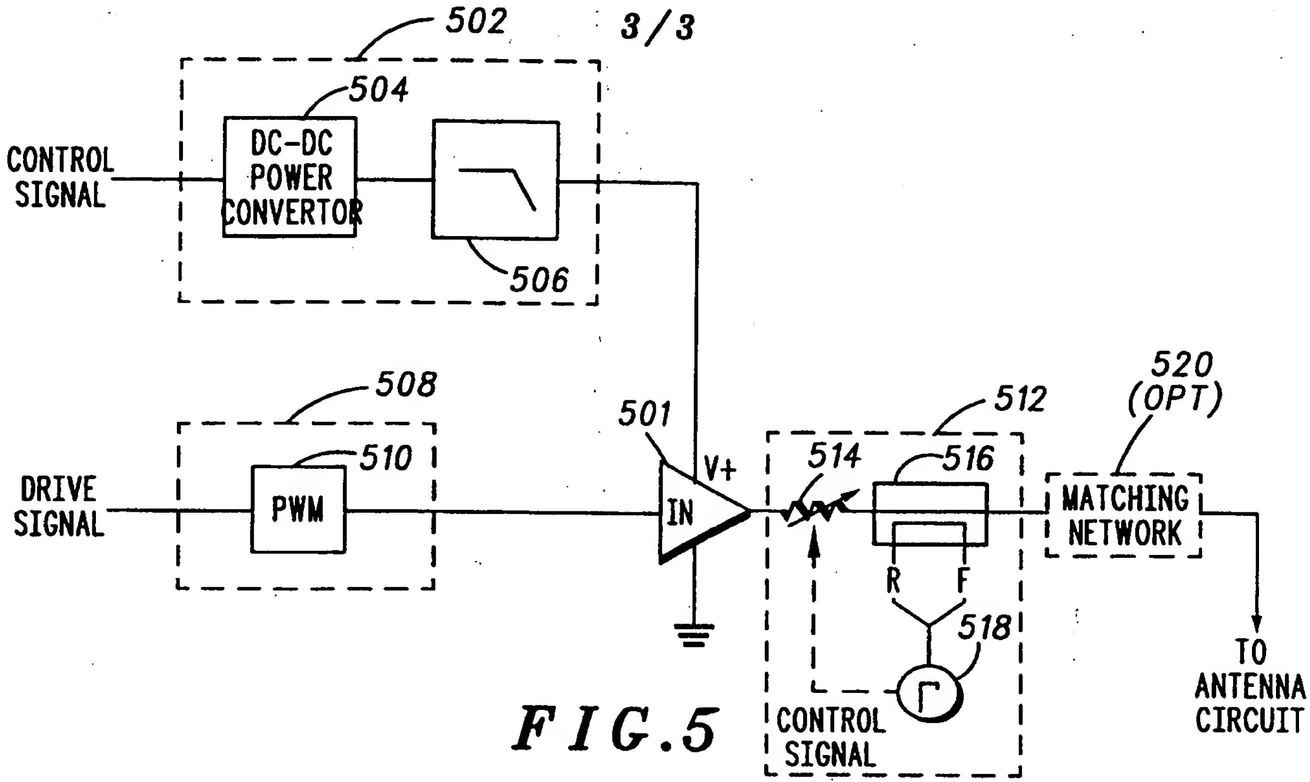

502
504
CONTROL SIGNAL
DC-DC POWER CONVERTOR
506
508
510
DRIVE SIGNAL
PWM
501
V+
IN
512
514
516
R
F
518
CONTROL SIGNAL
520 (OPT)
MATCHING NETWORK
TO ANTENNA CIRCUIT

FIG.5

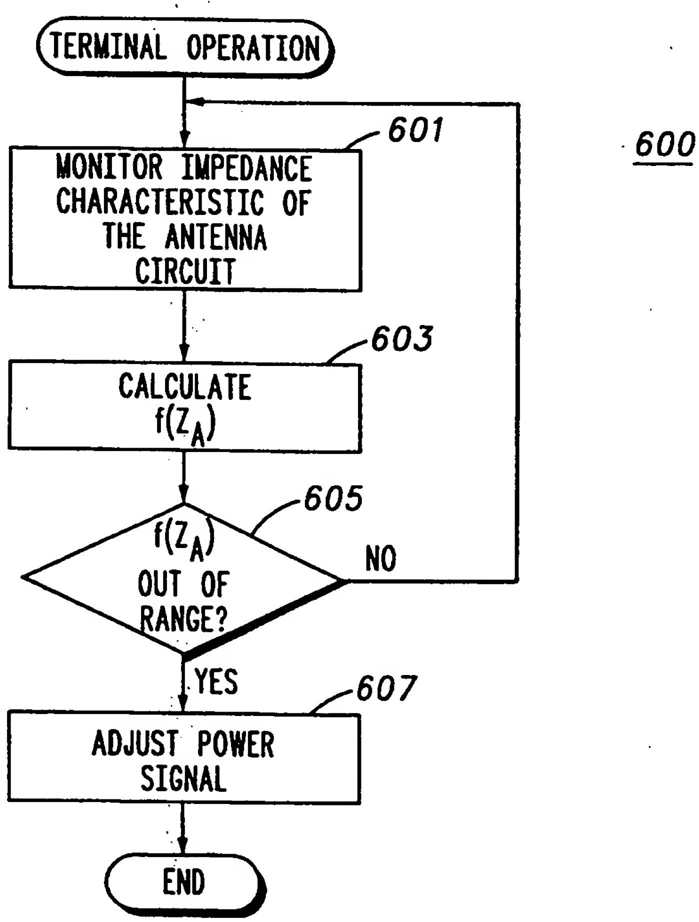

TERMINAL OPERATION
600
601
MONITOR IMPEDANCE CHARACTERISTIC OF THE ANTENNA CIRCUIT
603
CALCULATE f(Z_A)
605
f(Z_A) OUT OF RANGE?
NO
YES
607
ADJUST POWER SIGNAL
END

FIG.6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/27003

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04B 1/59
US CL : 455/343

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 455/343, 38.3, 522, 117, 127, 572 573 574

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APS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 07-321696 A (IKEFUJI) 08 DECEMBER 1995, ABSTRACT, TITLE, FIGURES 1 AND 3.	1,2,3
X -- Y	US 4,353,037 A (MILLER) 05 OCTOBER 1982, FIGURE 1.	6, 9 -- 7, 8, 10
Y	US 5,506,532 A (MILAZZO) 09 APRIL 1996, COL 1, LINES 24-64.	7
Y	US 3,852,669 A (BOWMAN ET AL.) 03 DECEMBER 1974, COL 2, LINES 47-50, FIGURES 1 AND 2	8
Y	US 3,646,397 A (RUTHENBERG ET AL.) 29 FEBRUARY 1972, ABSTRACT, FIGURE.	10

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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